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- Communist China -

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BOILING HEAT TRANSFER OF LIQUID METALS

- COMMUNIST CHINA -

[Following is a translation of an article by Lin Chi-fang (2651,4764,2455), Yang Yu-ch'i (2799,0645,7784), K'ung Fan-kuo (1313,4907,2654), Hseing Kuei-ch'en (6717,6311,5256), and Wang Chia-hsiang (3769,1367,4382) of the Dairen Engineering Institute in the Chinese-language periodical K'o-hseuh T'uang-pao (Scientia), Peiping, No. 24, 26 December 1959, pages 832-833.]

Due to the development of the atomic reactor, there has appeared apparatus of high coefficient of dynamics with high efficiency, and also the more frequently used high temperature high pressure techniques in the chemical industry, which have been drawing attention to the prospect of using melted liquid metal as a high temperature heatcapacitor. Especially, there are more advantages in using boiling heat transfer of liquid metals. So far, there is very little research work done in this aspect, and almost nothing as far as boiling metals under pressure is concerned.

We have conducted experiments on boiling Hg and Mg under various pressure. The experimental scope is as follows: Heat load $q=5,000$ $47,000$ kcal/m² hr., pressure $p=1$ ll absolute pressure, boiling point $t_k=355.9$ 524°C , Prandtl number $Pr=0.0098$ 0.0077 . The experimental results obtained are summarized as follows:

1. Boiling heat generation of pure Hg under pressure obtained by boiling Hg subjected to different pressures. Under standard pressure the thermal coefficient decreases with increases of q , this shows that $=4850-0.26$ kcal/m²hr^{0.46}. This is relatively close to the results obtained by Bromley's film type boiling analysis. Hence, under the standard pressure, film type of boiling appears under very small value of heat load. However, the thermal coefficient thus produced is more than 1.5 times greater than that calculated from the formula. When the pressure is increased, the boiling type changes immediately from film to nuclear and both heat load q and increase. This can be expressed by $=Aq^{0.46}$. However, the effect of pressure to is different from the conventional effect to liquid: pressure increases between 4-11 atms. with continuously decreasing, or $=7q^{0.46}p^{-0.29}$. The characteristic of heat generation of boiling Hg is its close relationship between its low Pr value and its non-permeability. According to the recent analysis of Aref'eva and Alad'ev, when the contact angle 140° , liquid requires very little work to leave the surface of the solid, and the gas bubbles spread easily through the surface forming film type boiling.

Because of the occurrence of low P_r value, thermal conductivity cannot be neglected, thus the thermal coefficient of the experimental value is much greater than that of the theoretically calculated value. Nuclear type boiling is formed because is reduced due to the fact that temperature increases with increasing pressure.

2. The boiling heat generation of Mg-Hg. The addition of a small quantity of Mg into Hg can improve the non-permeability of Hg and results in nuclear type of boiling. This property is improved further with additional quantity of Mg. Under the standard pressure, the experimental equation for Hg alloy containing Mg of 0.02% and 0.05% can be expressed by the experimental formula: $=Aq^n$, i.e., when containing 5.05% of Mg, and under the same value of heatload, it is 15-50% greater than that of containing 0.02% of Mg.

Mg Contents	A	N
0.02%	13.7	0.43
0.05%	2.43	0.63

This type of permeability affecting the value has been encountered during our previous experiment on boiling heat transfer of water. Figure 2 shows the experimental results obtained when containing 0.02% of Mg under various pressures, which have no evident effect on the boiling heat transfer of Hg alloy (the widely spread values resulted because of the thermal coefficient of the wall of the tube varied in the lower, middle, and upper parts). This is probably due to the effect on the non-permeability by the addition of Mg which produces a prominent effect on consequently shows very little effect by pressure. Besides, other physical properties are not affected by pressure to any great extent.

Conclusion:

(1) Pure Hg under standard pressure gives the film type of boiling. The experimental value of is greater than Bromley's theoretical heat transfer value of the film type. Therefore, his equation is not suitable for substances having a low P_r .

(2) Pure Hg boiling under pressure gives nuclear boiling characteristics, but the effect of pressure on thermal coefficient is opposite to that of ordinary liquids: between 4-11 atms., pressure increases while decreases.

The addition of a small quantity of Mg improves the permeability and also heat transfer efficiency, thus enables to increase. With an increasing amount of Mg, also increases, $=Aq^n$ while n also is increasing. When the Hg alloy contains 0.05% of Mg, the property of permeability appears the same as the boiling liquid. The change of pressure

does not affect greatly the heat transfer of the Mg-Hg system. However, under pressure, the nuclear type of boiling is characteristic of the system when containing 0.02% of Mg.

(4) The experimental results cannot be thoroughly interpreted since the theoretical explanation of the relationship of the nuclear type boiling shifting to film type did not consider the effect of permeability variations. It is also necessary to consider the effects of the changes of central density of vaporization and contact angle. The important effect is determined by the permeability between the substance and the heat transfer surface. Permeability is important as far as non-permeable liquids are concerned.

The experimental formulas obtained above for the boiling heat generation under pressure of Hg and Hg alloy can be provided as references for the producing and designing divisions.

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